RHODORA, Vol. 92, No. 871, pp. 166–204, 1990

THE MARSH VEGETATION OF THREE CONNECTICUT RIVER OXBOWS: A TEN-YEAR COMPARISON

MARJORIE M. HOLLAND AND C. JOHN BURK

ABSTRACT

The floras and vegetation of marshes in three large Connecticut River oxbows of differing ages in western Massachusetts were studied and compared in 1974 and again in 1984. Marshes at Hatfield in the most recently formed of the three oxbows occur in zones that parallel much of the old river bank. Marshes in Ned's Ditch, Northampton, an oxbow segment that was cut off from the river around 710 yr. B.P., occur within nine scattered ponds surrounded by swamp forest. Marshes at Whately in the oldest oxbow are confined to the vicinity of a single pond. In all three oxbows, a high marsh is dominated by *Onoclea sensibilis* and a low marsh by *Lemna minor* and *Nuphar variegatum*. Zones of emergent mid marsh vegetation are distinctive at each oxbow. Marshes at the two younger, regularly flooded oxbows share numerous species with the herb strata of adjacent swamp forests and remained relatively unchanged throughout the study period except for an increase in woody seedlings at the Hatfield high marsh. The Whately marshes share few species with adjacent forest; species richness in high and emergent zones of the Whately marshes declined sharply over the decade.

Key Words: marsh vegetation, wetlands, floodplains, Connecticut River, Massachusetts

INTRODUCTION

Marshes and other floodplain habitats along major streams in New England are spatiallly restricted and frequently disturbed by human activities. In western Massachusetts, extensive marsh vegetation occurs in four large oxbow lakes located along an 18 km stretch of the Connecticut River. A study of the vegetation of these marshes was included within broader studies of the phytosociology and geological development of the three older oxbows by M. M. Holland (Sackett, 1974, Unpubl. Master's thesis, Smith College, Northampton, Mass.; 1977, Unpubl. Ph.D. dissertation, U. Mass., Amherst). Field research for these earlier studies was conducted during the period 1973–1975. More recently, the relative ages of these oxbows have been established (Holland and Burk, 1982) and the herbaceous strata of swamp forests in the three older oxbows compared (Holland and Burk, 1984).

Within the context of an ongoing long-term study, observations of the Whately oxbow in the late 1970's and early 1980's indicated that marked changes in the vegetation had occurred some time after 1975. In addition, continuing investigations in the southeastern section of the prehistoric oxbow in Northampton, a large marsh complex which includes segments known as Hulbert's Pond and the Wood Duck Pond, have shown that the structure and composition of marsh vegetation were strongly influenced through the period 1969–1980 by changes in water quality in both the Connecticut River and in the Mill River, a tributary of the Connecticut that has preempted a portion of the oxbow (Robinton and Burk, 1971; Burk, 1973, 1977; Burk and Holland, 1981). Damage to vegetation caused by an oil spill in Hulbert's Pond and the Wood Duck Pond and changes through the recovery period (Burk, 1977) were also found to be similar to long-term marsh destruction in a Massachusetts salt marsh (Hampson and Moul, 1977, 1978).

Oxbows have classically been considered to support communities that are transitional between open water and adjacent terrestrial habitats. Clements and Shelford (1939) observed, for example, "that any portion of a community separated from the river channel, such as an oxbow, takes an immediate start as a land sere, characterized by increases in vegetation and the extinction of the terrigenous bottom community." Oxbows of differing ages in a given area can be considered as a chronosequence, a "spatial array" of sites that can be arranged in a pattern representing successional development from the initial stages available for colonization to the climax community of the region (Barbour et al., 1987; Jackson et al., 1988). Recent work, however, suggests that disturbance resulting from human activities may significantly influence the vegetation of apparent chronosequences and short-term effects of disturbance can be erroneously confused with long-term developmental trends (Jackson et al., 1988).

The major purpose of the present study was to examine the marshes of the three older oxbows and to compare the dominance (contribution to cover) and distribution of the vascular plant species present in 1974 with their dominance and distribution a decade later. Because of the changes documented at Hulbert's Pond and observed at the Whately oxbow, particular attention was paid to possible deterioration of the marsh environments, including changes in the status of non-native species that might be potential indicators of disturbance. Shelford (1963) estimated that convergence to forest vegetation in oxbows and other long submergence habitats would require "not less than 1,000 years" for completion in the Mississippi floodplain, and we did not expect to observe major successional changes over the course of the decade in New England, where vegetational processes proceed at a slower rate. However, Larson and Golet (1982), in an analysis of wetland habitats on the Massachusetts coastal plain, demonstrated that, while deep open water and forested wetland habitats are relatively stable, marshes frequently undergo transitions to shrub swamp or forested wetlands within a period of less than twenty years. Hence, the data were also examined for any indications that successional change might be occurring, including the relative degrees of overlap between the floras of the marshes and those of adjacent oxbow swamp forest habitats. The status of uncommon or rare native plants was also noted, since oxbow habitats often support relics of formerly more widespread floras and vegetation types (Holland and Burk, 1984).

THE STUDY SITES

Maps of the four oxbows and the locations of the study sites are included in Holland and Burk (1982, 1984). The 1840 Northampton oxbow remains predominantly open water with direct connections to the Connecticut River. Because this oxbow is used extensively for boating, water-skiing, and other recreational activities, its vegetation has been excluded from this investigation.

The Hatfield oxbow. The Hatfield oxbow, youngest (i.e., most recently separated from the main stem of the Connecticut) of the three sites that were studied, was depicted as two large ponds in early maps of the area. In March, 1936, during heavy flooding, the Connecticut River flowed directly through the Hatfield oxbow, causing extensive scouring of the bottom sediments (Collins and Schalk, 1937). Marshes are extensive in the Hatfield oxbow, occupying roughly two thirds of the old river bed as determined by aerial photographs, USGS topographic maps, local maps available from various sources, and ground and aerial reconnaissance. The oxbow is flooded from the Connecticut at least yearly, and in late May, 1984, was inundated for more than a week. The oxbow also receives more or less continuous flow from a small tributary known as Cow Bridge Brook.

Ned's Ditch. This prehistoric Northampton oxbow was separated from the Connecticut River around 710 ($\pm$130) yr. B.P. as determined by stratigraphy and radiocarbon dating (Holland and Burk, 1982). The southeastern portion of the oxbow contains the Hulbert's Pond marsh complex. Much of the remainder of the oxbow is included in a segment known as Ned's Ditch. Ned's Ditch is largely forested but contains an estimated 16 ha of marsh vegetation associated with seven ponds and two remnants of an earlier, abandoned bed of the Mill River. During periods of high water on the Connecticut, much of Ned's Ditch, including the forest, is flooded. The southeastern section of the prehistoric Northampton oxbow was excluded from this study because of the extensive work already conducted there (Robinton and Burk, 1971; Burk, 1973, 1977; Burk and Holland, 1981).

The Whately oxbow. The Whately oxbow is the oldest and most heavily forested of the four sites, lying largely above the present floodplain of the Connecticut. An estimated 8 ha of marsh vegetation occurs in the lower portions of the Whately site, surrounding and extending south of the remaining open water, a small pond fed and drained by a brook in the southeast corner of the oxbow. The area including the marsh was flooded in 1936, possibly for the first time since being raised above the active floodplain "many hundreds, perhaps even a few thousand years ago" (Jahns, 1947).

Full descriptions of the study sites are reported in Holland and Burk (1982, 1984).

MARSH HABITATS AND SAMPLING METHODS

The marsh habitats of the three oxbows exhibit a developmental topographic sequence from (1) more or less continuous vegetation along the edges of the old riverbed at Hatfield to (2) scattered ponds, each surrounded by marsh, at Ned's Ditch, to (3) a single remnant pond with associated marshes at Whately. At all three sites, wherever marsh vegetation occurs, three discrete zones of vegetation usually can be identified without difficulty in sequence from the river bank towards open water. These areas are comparable to the zones described by Daubenmire (1968) and other authors as stages in lake and pond succession, and are characterized by vascular plant species with life forms adapted to particular water depths. High marsh, forming a mat closest to the river bank, has herbaceous vegetation growing in constantly wet soil with no standing water under normal conditions during the time of year when vegetation is most fully developed. Mid marsh is characterized by emergent, anchored hydrophytes; standing water is usually present between plant stems. Low marsh is characterized by hydrophytes that are submerged, floating, or rooted with floating leaves. The submerged and floating forms may be either anchored or free-moving in the water [i.e., the "errant vascular hydrophytes" of Mueller-Dombois and Ellenberg (1974)].

Sampling techniques varied somewhat with site conditions.

Hatfield. At Hatfield in 1974, ten belt transects approximately 300 m long and 1 m wide were established across the oxbow at intervals of 575 m, as part of a general survey of vegetation types (Holland and Burk, 1984; Sackett, 1977 op. cit.). Marsh vegetation occurred on eight transects and was accessible on six. On each transect sampled, ten 0.5 m × 0.5 m quadrats were evenly spaced in each zone at intervals of 1 m on a baseline perpendicular to the transect. The baselines were situated to avoid transitional areas between zones; quadrats that were overlaid by flood debris were relocated to the nearest undisturbed vegetation on the baseline. In each quadrat, a visual estimate of percentage cover was determined and recorded for each vascular plant species present. On some transects, one of the three typical zones was absent. On other transects, one or more zones of marsh occurred at two discrete and separate intervals along the transect and were included twice in sampling. In all, eight areas of high marsh, six areas of mid marsh, and six areas of low march were sampled.

Ned's Ditch. In 1974, a line transect was run from south to north across each of the seven ponds and two sections of the old Mill River bed. All nine marsh units are hereafter referred to as ponds; maps of Ned's Ditch with locations of the ponds are in Sackett (1974, op. cit.). Usually the transect crossed the sequence high marsh/mid marsh/low marsh/mid marsh/high marsh. In each pond, 0.5 m × 0.5 m quadrats were placed and sampled as at Hatfield in the southernmost zone of high and mid marsh and in the center of low marsh. Occasionally one zone was lacking. Five areas of high marsh, seven of mid marsh, and nine of low marsh were sampled in 1974.

Whately. Marsh vegetation was sampled as at Hatfield on two transects, one crossing the pond and the other crossing its drainage. Two areas of high marsh, two of mid marsh, and two of low marsh were sampled in 1974.

In 1984, all transects with marsh vegetation were relocated and vegetation sampled as before. In Ned's Ditch, four new zones had become established and seven zones of high marsh, nine of mid marsh, and nine of low marsh could be studied. The sampling procedure, which was regular and non-random, assured that the same zones on the same transects across the oxbow were studied in both 1974 and 1984. The baselines on which the quadrats were situated were not necessarily the same, however, particularly in instances where the position of the zones along the transects may have shifted.

For analysis and comparison, Table 1 was prepared to document the floras of the marshes in 1974 and 1984 as determined by quantitative sampling. Average percent cover and frequency of each species sampled in each of the three zones in each oxbow during 1974 and 1984 are listed with cover values and frequencies rounded off to the nearest whole number. Table 1 also includes summed cover values for each zone, computed on the basis of actual rather than rounded data, and species richness, the total number of species present in each zone. Cover data are particularly useful because they allow comparisons of the amount of surface occupied by plants of differing life forms (Daubenmire, 1968). Frequency, expressed as percent occurrence in a given number of sample plots, serves as a measurement of the distribution of the species throughout the zone. The relative importance of cover and frequency in assessing changes in vegetation depends to a large extent on the life forms of the plants involved. Tree seedlings may occur, for example, with low cover but high frequency in a zone, and their frequency might be interpreted as an indication of successful reproduction and potential change (Mueller-Dombois and Ellenberg, 1974). In contrast, low cover and high frequency of errant hydrophytes such as *Lemna minor* L. in the upper marsh zones or swamp forest of the oxbows may simply reflect the persistence of the plants after being stranded after periods of high water (Holland and Burk, 1984).

Because the placement of the quadrats in this study was not random, probability statistics are inappropriate as aids in interpreting whether significant vegetational change has occurred (Mueller-Dombois and Ellenberg, 1974; Barbour et al., 1987). However, the data do lend themselves to comparisons through indices of similiarity. We have used the Simpson Index of Resemblance (Simpson, 1965) to compare the taxonomic composition of the floras of the marshes (Table 2), combining data from

Table 1. Percent cover (C), frequency (F), zone(s), and year(s) of occurrence of species sampled in each zone of the three oxbow marshes in 1974 and 1984. **H** indicates high marsh; **M** indicates mid marsh; **L** indicates low marsh. Total cover is the sum of actual cover values for each species.

		Hatfield				Ned's Ditch	
		1974		1984		1974	
Species	Zone	C	F	C	F	C	F
Herbs and vines							
Actaea rubra (Ait.) Willd.	H	–	–	<.5	1	–	–
Agrostis alba L.	H	–	–	–	–	1	10
	M	–	–	–	–	–	
	L	–	–	–	–	<.5	2
Alisma subcordatum Raf.	H	–	–	–	–	<.5	4
	M	–	–	–	–	–	–
Amphicarpa bracteata (L.) Fern.	H	–	–	<.5	1	–	–
Apios americana Medic.	H	3	25	2	16	1	6
Arisaema triphyllum (L.) Schott	H	–	–	<.5	3	<.5	2
Athyrium filix-femina (L.) Roth	H	–	–	–	–	–	–
Bidens tripartita L.	H	<.5	8	1	19	<.5	2
	M	1	5	<.5	10	–	–
Boehmeria cylindrica (L.) Sw.	H	1	28	2	23	<.5	6
	M	<.5	3	<.5	9	–	–
	L	<.5	5	–	–	–	–
Cabomba caroliniana Gray	M	1	30	2	13	–	–
	L	3	13	4	15	–	–
Calamagrostis canadensis (Michx.) Nutt.	H	<.5	6	–	–	–	–
	M	<.5	2	–	–	–	–

Table 1. Continued.

Species	Zone	Ned's Ditch 1984 C	Ned's Ditch 1984 F	Whately 1974 C	Whately 1974 F	Whately 1984 C	Whately 1984 F
Herbs and vines							
Actaea rubra (Ait.) Willd.	H	–	–	–	–	–	–
Agrostis alba L.	H	–	–	6	40	–	–
	M	–	–	4	30	–	–
	L	–	–	–	–	–	–
Alisma subcordatum Raf.	H	–	–	–	–	–	–
	M	–	–	<.5	5	–	–
Amphicarpa bracteata (L.) Fern.	H	–	–	–	–	–	–
Apios americana Medic.	H	5	26	–	–	1	10
Arisaema triphyllum (L.) Schott	H	–	–	–	–	–	–
Athyrium filix-femina (L.) Roth	H	–	–	2	20	–	–
Bidens tripartita L.	H	3	47	–	–	<.5	5
	M	4	49	<.5	10	–	–
Boehmeria cylindrica (L.) Sw.	H	<.5	1	2	30	<.5	15
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Cabomba caroliniana Gray	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Calamagrostis canadensis (Michx.) Nutt.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Callitriche heterophylla Pursh	H	<.5	9	<.5	4	–	–
	L	1	13	–	–	–	–
Cardamine pensylvanica Muhl.	H	<.5	1	–	–	–	–
	M	–	–	–	–	–	–
Carex spp.[1]	H	1	15	2	28	–	–
	M	<.5	7	1	15	–	–
	L	–	–	<.5	3	–	–
Ceratophyllum demersum L.	M	<.5	17	2	13	–	–
	L	3	17	2	12	–	–
Cicuta maculata L.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
	L	<.5	2	–	–	–	–
Convolvulus sepium L.	H	<.5	3	–	–	–	–
Cuscuta gronovii Willd.	H	<.5	1	–	–	–	–
	M	<.5	13	<.5	5	–	–
	L	<.5	2	–	–	–	–
Dryopteris spinulosa (O. F. Muell.) Watt	H	<.5	1	–	–	3	22
	M	–	–	–	–	<.5	4
Dulichium arundinaceum (L.) Britt.	H	–	–	1	3	–	–
	M	–	–	–	–	–	–
Echinocystis lobata (Michx.) T. & G.	H	<.5	3	–	–	–	–
Eleocharis acicularis (L.) R. & S.	H	–	–	–	–	4	12
	M	–	–	–	–	<.5	3

Table 1. Continued.

Species	Zone	Ned's Ditch 1984 C	Ned's Ditch 1984 F	Whately 1974 C	Whately 1974 F	Whately 1984 C	Whately 1984 F
Callitriche heterophylla Pursh	H	–	–	–	–	–	–
	L	–	–	–	–	–	–
Cardamine pensylvanica Muhl.	H	–	–	–	–	<.5	5
	M	–	–	<.5	5	–	–
Carex spp.[1]	H	–	–	9	50	<.5	5
	M	–	–	3	15	–	–
	L	–	–	–	–	–	–
Ceratophyllum demersum L.	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Cicuta maculata L.	H	–	–	3	35	–	–
	M	–	–	<.5	15	–	–
	L	–	–	–	–	–	–
Convolvulus sepium L.	H	–	–	–	–	–	–
Cuscuta gronovii Willd.	H	–	–	<.5	5	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Dryopteris spinulosa (O. F. Muell.) Watt	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Dulichium arundinaceum (L.) Britt.	H	1	11	–	–	–	–
	M	<.5	2	–	–	–	–
Echinocystis lobata (Michx.) T. & G.	H	–	–	–	–	–	–
Eleocharis acicularis (L.) R. & S.	H	1	4	–	–	–	–
	M	–	–	–	–	3	20

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Eleocharis intermedia (Muhl.) Schultes	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Eleocharis obtusa (Willd.) Schultes	H	<.5	1	–	–	–	–
Elodea nuttallii (Planch.) St. John	M	1	7	<.5	1	–	–
	L	3	12	–	–	–	–
Equisetum fluviatile L.	H	<.5	9	3	11	–	–
	M	<.5	2	2	11	–	–
	L	<.5	5	<.5	3	–	–
Eupatorium maculatum L.	H	–	–	<.5	1	–	–
Eupatorium perfoliatum L.	H	–	–	–	–	–	–
Galium aparine L.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Galium trifidum L.	H	<.5	18	1	41	<.5	6
	M	<.5	3	<.5	5	<.5	1
	L	<.5	2	–	–	–	–
Geum canadense Jacq.	H	–	–	–	–	–	–
Glechoma hederacea L.	H	–	–	–	–	–	–
Glyceria canadensis (Michx.) Trin.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Glyceria striata (Lam.) Hitchc.	H	1	6	–	–	–	–
Hypericum perforatum L.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–

Table 1. Continued.

		Ned's Ditch		Whately			
		1984		1974		1984	
Species	Zone	C	F	C	F	C	F
Eleocharis intermedia (Muhl.) Schultes	H	–	–	1	15	–	–
	M	–	–	1	10	–	–
Eleocharis obtusa (Willd.) Schultes	H	–	–	–	–	–	–
Elodea nuttallii (Planch.) St. John	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Equisetum fluviatile L.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Eupatorium maculatum L.	H	–	–	–	–	–	–
Eupatorium perfoliatum L.	H	–	–	1	15	–	–
Galium aparine L.	H	–	–	4	45	–	–
	M	–	–	1	15	–	–
Galium trifidum L.	H	<.5	6	–	–	1	5
	M	–	–	–	–	1	5
	L	–	–	–	–	–	–
Geum canadense Jacq.	H	–	–	<.5	5	–	–
Glechoma hederacea L.	H	–	–	<.5	5	–	–
Glyceria canadensis (Michx.) Trin.	H	–	–	–	–	1	5
	M	–	–	–	–	1	10
Glyceria striata (Lam.) Hitchc.	H	–	–	–	–	–	–
Hypericum perforatum L.	H	–	–	<.5	10	–	–
	M	–	–	1	5	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Hypericum virginicum L.	H	–	–	–	–	–	–
Impatiens capensis Meerb.	H	1	13	<.5	4	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Iris versicolor L.	L	<.5	2	–	–	–	–
Juncus effusus L.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Leersia oryzoides (L.) Sw.	H	1	14	2	40	<.5	4
	M	14	17	3	13	<.5	1
	L	2	17	1	10	–	–
Lemna minor L.	H	1	10	<.5	25	<.5	16
	M	57	93	18	75	2	71
	L	28	62	27	73	1	56
Lindernia dubia (L.) Pennell	H	<.5	5	<.5	3	–	–
	M	<.5	2	–	–	–	–
Ludwigia palustris (L.) Ell.	H	1	6	–	–	4	10
	M	1	2	–	–	–	–
Ludwigia polycarpa Short & Peter	H	–	–	–	–	<.5	4
Lycopus virginicus L.	H	–	–	–	–	–	–
	M	<.5	2	<.5	1	–	–
Lysimachia ciliata L.	H	–	–	<.5	1	–	–
Lysimachia terrestris (L.) B.S.P.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–

Table 1. Continued.

Species	Zone	Ned's Ditch		Whately			
		1984		1974		1984	
		C	F	C	F	C	F
Hypericum virginicum L.	H	1	8	–	–	–	–
Impatiens capensis Meerb.	H	–	–	8	55	9	45
	M	–	–	8	35	14	40
	L	–	–	2	10	–	–
Iris versicolor L.	L	–	–	–	–	–	–
Juncus effusus L.	H	–	–	7	30	–	–
	M	–	–	<.5	5	–	–
Leersia oryzoides (L.) Sw.	H	<.5	7	6	35	1	15
	M	2	19	17	45	–	–
	L	<.5	3	–	–	–	–
Lemna minor L.	H	<.5	6	–	–	<.5	5
	M	1	74	12	60	5	50
	L	1	50	1	75	1	50
Lindernia dubia (L.) Pennell	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Ludwigia palustris (L.) Ell.	H	–	–	<.5	5	–	–
	M	–	–	<.5	10	–	–
Ludwigia polycarpa Short & Peter	H	–	–	–	–	–	–
Lycopus virginicus L.	H	–	–	2	25	–	–
	M	–	–	–	–	–	–
Lysimachia ciliata L.	H	–	–	1	10	–	–
Lysimachia terrestris (L.) B.S.P.	H	1	11	1	10	–	–
	M	–	–	<.5	5	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Lysimachia nummularia L.	H	—	—	—	—	<.5	4
Lythrum salicaria L.	H	1	3	—	—	—	—
	M	2	15	—	—	—	—
Maianthemum canadense Desf.	H	<.5	1	—	—	—	—
Matteuccia struthiopteris (L.) Tod.	H	1	9	—	—	<.5	2
Mimulus ringens L.	M	—	—	<.5	3	—	—
Myosotis scorpiodes L.	M	—	—	—	—	—	—
	L	—	—	—	—	—	—
Nuphar variegatum Engelm.	M	—	—	1	3	2	25
	L	7	17	11	25	7	53
Nymphaea odorata Ait.	M	—	—	1	4	—	—
	L	—	—	7	23	—	—
Onoclea sensibilis L.	H	50	93	43	93	15	44
	M	—	—	4	9	—	—
	L	—	—	<.5	2	—	—
Osmunda regalis L.	H	<.5	1	2	3	6	16
	M	—	—	—	—	2	4
Oxalis europaea Jord.	H	<.5	6	<.5	8	—	—
Panicum lanuginosum Ell.	H	—	—	<.5	1	—	—
Panicum sp.	H	—	—	—	—	—	—
Parthenocissus quinquefolia (L.) Planch.	H	<.5	14	<.5	3	—	—
	M	<.5	2	—	—	—	—

Table 1. Continued.

Species	Zone	Ned's Ditch 1984 C	Ned's Ditch 1984 F	Whately 1974 C	Whately 1974 F	Whately 1984 C	Whately 1984 F
Lysimachia nummularia L.	H	<.5	1	—	—	—	—
Lythrum salicaria L.	H	—	—	—	—	—	—
	M	—	—	—	—	—	—
Maianthemum canadense Desf.	H	—	—	—	—	—	—
Matteuccia struthiopteris (L.) Tod.	H	1	6	—	—	—	—
Mimulus ringens L.	M	—	—	—	—	—	—
Myosotis scorpiodes L.	M	—	—	—	—	<.5	5
	L	—	—	—	—	1	5
Nuphar variegatum Engelm.	M	7	17	—	—	—	—
	L	12	36	12	25	16	30
Nymphaea odorata Ait.	M	—	—	—	—	—	—
	L	—	—	—	—	11	30
Onoclea sensibilis L.	H	23	47	14	50	56	95
	M	—	—	2	10	8	25
	L	—	—	—	—	—	—
Osmunda regalis L.	H	20	40	—	—	—	—
	M	—	—	—	—	—	—
Oxalis europaea Jord.	H	—	—	<.5	10	—	—
Panicum lanuginosum Ell.	H	—	—	—	—	4	25
Panicum sp.	H	<.5	1	—	—	—	—
Parthenocissus quinquefolia (L.) Planch.	H	—	—	—	—	<.5	5
	M	—	—	—	—	—	—

Table 1. Continued.

Species	Zone	Hatfield 1974 C	Hatfield 1974 F	Hatfield 1984 C	Hatfield 1984 F	Ned's Ditch 1974 C	Ned's Ditch 1974 F
Peltandra virginica (L.) Schott & Endl.	H	–	–	<.5	8	–	–
	M	10	35	14	25	–	–
Pilea pumila (L.) Gray	H	–	–	<.5	1	–	–
	M	–	–	<.5	1	–	–
Poa palustris L.	H	–	–	–	–	–	–
Polygonum amphibium L.	H	–	–	–	–	<.5	2
Polygonum arifolium L.	H	–	–	–	–	–	–
Polygonum hydropiperoides Michx.	M	–	–	1	7	–	–
Polygonum sagittatum L.	H	<.5	1	–	–	–	–
Polygonum spp.	L	–	–	1	5	–	–
Pontederia cordata L.	H	<.5	1	–	–	–	–
Potamogeton pectinatus L.	M	–	–	–	–	1	36
	L	<.5	2	–	–	7	37
Ranunculus flabellaris Raf.	H	–	–	–	–	<.5	10
	M	–	–	–	–	<.5	7
	L	–	–	–	–	<.5	1
Rhus radicans L.	H	<.5	1	<.5	1	<.5	2
Rumex crispus L.	M	–	–	–	–	–	–
Sagittaria latifolia Willd.	H	<.5	1	<.5	1	–	–
	M	<.5	2	1	8	–	–
	L	–	–	<.5	2	<.5	6
Scirpus atrovirens Willd.	H	–	–	–	–	–	–

Table 1. Continued.

Species	Zone	Ned's Ditch 1984 C	Ned's Ditch 1984 F	Whately 1974 C	Whately 1974 F	Whately 1984 C	Whately 1984 F
Peltandra virginica (L.) Schott & Endl.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Pilea pumila (L.) Gray	H	–	–	–	–	1	10
	M	–	–	–	–	–	–
Poa palustris L.	H	–	–	5	30	–	–
Polygonum amphibium L.	H	–	–	–	–	–	–
Polygonum arifolium L.	H	–	–	<.5	5	–	–
Polygonum hydropiperoides Michx.	M	–	–	–	–	–	–
Polygonum sagittatum L.	H	–	–	13	70	<.5	5
Polygonum spp.	L	–	–	–	–	–	–
Pontederia cordata L.	H	–	–	–	–	–	–
Potamogeton pectinatus L.	M	1	11	–	–	–	–
	L	5	28	–	–	–	–
Ranunculus flabellaris Raf.	H	1	13	–	–	–	–
	M	1	19	–	–	–	–
	L	9	13	–	–	–	–
Rhus radicans L.	H	<.5	3	–	–	–	–
Rumex crispus L.	M	–	–	–	–	1	5
Sagittaria latifolia Willd.	H	–	–	2	25	–	–
	M	1	7	<.5	10	–	–
	L	1	9	–	–	–	–
Scirpus atrovirens Willd.	H	–	–	1	10	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Scutellaria lateriflora L.	H	<.5	14	<.5	4	–	–
	M	<.5	2	–	–	–	–
	L	<.5	2	–	–	–	–
Sium suave Walt.	H	1	5	–	–	<.5	8
	M	1	10	<.5	1	<.5	3
	L	–	–	–	–	–	–
Solanum dulcamara L.	M	<.5	2	–	–	–	–
	L	<.5	2	–	–	–	–
Solidago spp.	H	<.5	1	–	–	–	–
	M	<.5	2	–	–	–	–
Sparganium americanum Nutt.	M	–	–	–	–	–	–
	L	–	–	–	–	<.5	4
Sparganium androcladum (Engelm.) Morong	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Spirodela polyrhiza (L.) Schleid.	H	<.5	4	<.5	8	<.5	4
	M	2	68	1	43	1	60
	L	1	33	<.5	33	<.5	29
Symplocarpus foetidus (L.) Nutt.	H	<.5	1	<.5	1	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Taraxacum officinale Weber	H	<.5	3	–	–	–	–
Thalictrum polygamum Muhl.	H	–	–	1	14	–	–

Table 1. Continued.

Species	Zone	Ned's Ditch		Whately			
		1984		1974		1984	
		C	F	C	F	C	F
Scutellaria lateriflora L.	H	–	–	1	15	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Sium suave Walt.	H	1	10	<.5	5	–	–
	M	6	44	–	–	–	–
	L	1	9	–	–	–	–
Solanum dulcamara L.	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Solidago spp.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–
Sparganium americanum Nutt.	M	3	26	–	–	–	–
	L	1	9	–	–	–	–
Sparganium androcladum (Engelm.) Morong	M	–	–	7	40	13	35
	L	–	–	17	35	2	20
Spirodela polyrhiza (L.) Schleid.	H	–	–	–	–	–	–
	M	<.5	39	2	50	–	–
	L	<.5	19	<.5	30	–	–
Symplocarpus foetidus (L.) Nutt.	H	–	–	–	–	6	15
	M	–	–	1	5	20	50
	L	–	–	–	–	2	5
Taraxacum officinale Weber	H	–	–	–	–	–	–
Thalictrum polygamum Muhl.	H	–	–	–	–	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Thelypteris palustris Schott	H	–	–	–	–	–	–
	M	–	–	<.5	1	–	–
Typha latifolia L.	H	–	–	<.5	8	–	–
	M	–	–	<.5	6	–	–
Urtica dioica L.	M	–	–	–	–	–	–
Utricularia vulgaris L.	M	–	–	–	–	<.5	7
	L	–	–	–	–	2	8
Vallisneria americana Michx.	L	–	–	–	–	–	–
Verbena hastata L.	H	–	–	–	–	–	–
Vitis spp.[2]	H	7	29	1	3	17	32
	M	1	5	–	–	1	6
Wolffia columbiana Karst.	H	–	–	<.5	5	–	–
	M	1	40	<.5	39	–	–
	L	<.5	20	<.5	45	–	–
Shrubs and woody seedlings							
Acer rubrum L.	H	<.5	1	<.5	6	–	–
Acer saccharinum L.	H	<.5	14	1	36	<.5	18
	M	<.5	2	–	–	<.5	4
Alnus rugosa (DuRoi) Spreng	H	1	6	–	–	–	–
Cephalanthus occidentalis L.	H	1	4	2	9	<.5	8
	M	<.5	2	2	3	68	83
	L	<.5	2	–	–	–	–

Table 1. Continued.

Species	Zone	Ned's Ditch 1984 C	Ned's Ditch 1984 F	Whately 1974 C	Whately 1974 F	Whately 1984 C	Whately 1984 F
Thelypteris palustris Schott	H	5	26	–	–	–	–
	M	–	–	–	–	–	–
Typha latifolia L.	H	–	–	5	35	–	–
	M	–	–	16	40	–	–
Urtica dioica L.	M	–	–	–	–	1	5
Utricularia vulgaris L.	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Vallisneria americana Michx.	L	–	–	–	–	1	15
Verbena hastata L.	H	–	–	1	10	–	–
Vitis spp.[2]	H	8	29	1	10	–	–
	M	–	–	–	–	–	–
Wolffia columbiana Karst.	H	–	–	–	–	–	–
	M	<.5	6	–	–	<.5	20
	L	<.5	7	–	–	<.5	40
Shrubs and woody seedlings							
Acer rubrum L.	H	–	–	–	–	–	–
Acer saccharinum L.	H	3	29	–	–	–	–
	M	<.5	2	–	–	–	–
Alnus rugosa (DuRoi) Spreng	H	–	–	1	10	–	–
Cephalanthus occidentalis L.	H	6	14	–	–	–	–
	M	22	41	–	–	–	–
	L	–	–	–	–	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Cornus amomum Mill.	H	3	21	5	18	–	–
	M	1	2	<.5	4	–	–
Cornus stolonifera Michx.	H	–	–	–	–	23	44
	M	–	–	–	–	1	4
Decodon verticillatus (L.) Ell.	H	1	10	2	5	–	–
	M	28	62	10	43	–	–
	L	2	13	1	12	–	–
Ilex verticillata (L.) Gray	H	–	–	–	–	1	4
Prunus sp.	H	<.5	1	–	–	–	–
Quercus coccinea Muenchh.	H	–	–	–	–	–	–
Quercus palustris Muenchh.	H	–	–	–	–	–	–
Rosa palustris Marsh.	H	–	–	<.5	1	–	–
Rubus spp.	H	–	–	–	–	–	–
Salix spp.	H	<.5	1	1	1	<.5	2
	M	–	–	–	–	–	–
	L	<.5	2	–	–	<.5	11
Sambucus canadensis L.	H	–	–	–	–	–	–
Spiraea latifolia (Ait.) Borkh.	H	–	–	–	–	–	–
Ulmus rubra Muhl.	H	<.5	1	<.5	1	–	–
	M	–	–	<.5	3	–	–

Table 1. Continued.

Species	Zone	Ned's Ditch		Whately			
		1984		1974		1984	
		C	F	C	F	C	F
Cornus amomum Mill.	H	–	–	–	–	<.5	5
	M	–	–	–	–	1	5
Cornus stolonifera Michx.	H	6	27	–	–	–	–
	M	–	–	–	–	–	–
Decodon verticillatus (L.) Ell.	H	<.5	1	–	–	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Ilex verticillata (L.) Gray	H	<.5	3	–	–	–	–
Prunus sp.	H	–	–	<.5	5	–	–
Quercus coccinea Muenchh.	H	–	–	<.5	5	–	–
Quercus palustris Muenchh.	H	1	7	–	–	–	–
Rosa palustris Marsh.	H	–	–	3	15	–	–
Rubus spp.	H	–	–	–	–	<.5	5
Salix spp.	H	–	–	3	10	–	–
	M	–	–	–	–	–	–
	L	–	–	–	–	–	–
Sambucus canadensis L.	H	–	–	1	10	1	5
Spiraea latifolia (Ait.) Borkh.	H	–	–	1	10	–	–
Ulmus rubra Muhl.	H	–	–	–	–	–	–
	M	–	–	–	–	–	–

Table 1. Continued.

Species	Zone	Hatfield				Ned's Ditch	
		1974		1984		1974	
		C	F	C	F	C	F
Viburnum recognitum Fern.	H	–	–	1	5	5	10
	M	–	–	–	–	<.5	1
Total species	H	47		42		29	
	M	30		29		17	
	L	21		14		10.	
% Cover	H	78		74		82	
	M	122		65		78	
	L	51		56		17	

[1] Includes identifiable *C. intumescens* Rudge at Whately (1974), *C. stricta* Lam. at Hatfield (1984), and *C. tribuloides* Wahlenb. at Hatfield (1974, 1984).
[2] Mostly *V. riparia* Michx.

Table 1. Continued.

Species	Zone	Ned's Ditch		Whately			
		1984		1974		1984	
		C	F	C	F	C	F
Viburnum recognitum Fern.	H	1	4	–	–	–	–
	M	–	–	–	–	1	5
Total species	H	28		38		19	
	M	14		21		14	
	L	10		5		8	
% Cover	H	88		104		81	
	M	50		76		68	
	L	30		32		32	

Table 2. The Simpson Index of Resemblance comparing selected floras of the oxbow marshes and 1973–1975 swamp forest herb strata (SFHS) at the specific level.

Floras Compared	Resemblance
Hatfield marsh 1974/Hatfield marsh 1984	69.2
Ned's Ditch marsh 1974/Ned's Ditch marsh 1984	78.1
Whately marsh 1974/Whately marsh 1984	44.4
Hatfield marsh 1974/Hatfield SFHS	60.0
Ned's Ditch marsh 1974/Ned's Ditch SFHS	75.8
Whately marsh 1974/Whately SFHS	6.9
Hatfield marsh 1984/Hatfield SFHS	51.9
Ned's Ditch marsh 1984/Ned's Ditch SFHS	69.7
Whately marsh 1984/Whately SFHS	7.4
Hatfield marsh 1974/Ned's Ditch marsh 1974	60.6
Ned's Ditch marsh 1974/Whately marsh 1974	39.4
Hatfield marsh 1974/Whately marsh 1974	48.8
Hatfield marsh 1984/Ned's Ditch marsh 1984	65.6
Ned's Ditch marsh 1984/Whately marsh 1984	40.7
Hatfield marsh 1984/Whately marsh 1984	63.0
Hatfield SFHS/Ned's Ditch SFHS	36.0
Ned's Ditch SFHS/Whately SFHS	13.0
Hatfield SFHS/Whately SFHS	21.0
Whately marsh 1974/Hatfield SFHS	53.5
Whately marsh 1974/Ned's Ditch SFHS	34.9
Whately marsh 1984/Hatfield SFHS	40.7
Whately marsh 1984/Ned's Ditch SFHS	29.6
Hatfield marsh 1974/Ned's Ditch SFHS	40.0
Hatfield marsh 1984/Ned's Ditch SFHS	36.0
Ned's Ditch marsh 1974/Hatfield SFHS	45.5
Ned's Ditch marsh 1984/Hatfield SFHS	40.6

high, mid, and low marsh at each sampling period, and to compare the floras of the marshes with the floras of the herb strata of adjacent oxbow swamp forests during the period 1973–1975 (data from Holland and Burk, 1984). Simpson's Index of Resemblance (100 c/n1 in which c is the number of species common to the two floras and n1 the total number of species in the smaller flora) has been used in previous comparisons within the New England flora (Lauermann and Burk, 1976; Holland and Sorrie, 1989). The index seems particularly useful when floras of approximately equal sizes occurring in a common area are compared.

Additional marsh species observed and collected at the sites but never sampled are listed in Sackett (1974, op. cit.; 1977, op.

cit.); most of these species are uncommon to rare and occur in transitional or disturbed habitats at the edges of the marshes. Data representing specimens of *Carex, Polygonum, Prunus, Rubus, Salix,* and *Solidago* that could not be identified to species are grouped under each genus in the tables. For purposes of consistency, nomenclature follows Fernald (1950) except in the cases of (1) *Matteuccia,* which is conserved over *Pteretis* as used in that manual, (2) *Thelypteris,* now generally accepted as the genus of the marsh fern, *T. palustris,* which Fernald included in *Dryopteris,* and (3) *Bidens tripartita* L. to include *B. comosa* and *B. connata.* Authorities of all known species discussed herein are given in Table 1. Specimens of all taxa collected have been deposited in SCH.

RESULTS AND DISCUSSION

General Observations

Metzler and Damman (1985) have documented marked annual changes in the vegetation of certain floodplain habitats, particularly undrained sloughs, as a result of varying flood patterns in the lower reaches of the Connecticut River. The Massachusetts oxbow habitats, which are upstream from natural tidal influences, show more predictable year-to-year relationships. Comparisons of the Simpson Index of Resemblance indicate that the floras of the Ned's Ditch marshes showed the least change over the interval 1974–1979 (Table 2). Somewhat greater change occurred in the floras of the Hatfield marshes, while the Whately marshes changed quite drastically.

The herbaceous strata of the oxbow swamp forests are distinctive, with relatively few species occurring in all three oxbows (Holland and Burk, 1984). This uniqueness of the individual swamp forest floras is reflected in their relatively low similarities of resemblance (Table 2). Overall, the floras of the marshes of the three oxbows are more similar to one another than to the floras of the adjacent swamp forests. This similarity increased slightly over the period 1974–1984 (Table 2); a group of species that includes *Apios americana, Bidens tripartita, Boehmeria cyclindrica, Leersia oryzoides, Lemna minor, Ludwigia palustris, Nuphar variegatum, Onoclea sensibilis, Sagittaria latifolia, Sium suave, Spirodela polyrhiza, Viburnum recognitum, Vitis riparia,* and *Wolffia columbiana* was sampled in all three marshes during at least one sampling period.

The high marsh zones of the three oxbows tend to be most similar to one another (Sackett, 1977, op. cit.). This similarity at Hatfield and Ned's Ditch has persisted for a decade, while, with the increasing abundance of *Onoclea sensibilis,* high marsh at Whately increasingly resembles that of the other two oxbows. The low marsh zones of the three oxbows, dominated by varying proportions of *Lemna minor* and *Nuphar variegatum,* are also similar, but mid marsh emergent plant communities have remained distinctive at each oxbow through the study period.

Total cover and species richness were usually highest in high marsh and lowest in low marsh; the exceptions to this were observed during the relatively dry summer of 1974 when crowded populations of *Lemna minor* filled the mid marsh at Hatfield and heavy growth of *Cephalanthus occidentalis* shaded adjacent high marsh at Ned's Ditch.

The Hatfield Oxbow

Swamp forests adjacent to the Hatfield marshes are dominated by an overstory of *Populus deltoides* in association with *Acer saccharinum,* arborescent *Alnus rugosa,* and smaller specimens of *Acer negundo, A. rubrum, Fraxinus pensylvanica, Salix nigra,* and other trees. *Populus deltoides* is not regenerating and will probably be replaced by more shade-tolerant species.

The flora of the Hatfield marsh shows a strong similarity to the flora of the herb strata of the Hatfield swamp forest (Table 2). Over three-fourths of the 40 herbaceous species sampled in the understory of the swamp forest in 1974 and 1975 (Sackett, 1977 op. cit.; Holland and Burk, 1982) also occurred in the Hatfield marshes (34 species in 1974, 32 in 1984). Species that were present in the marsh in 1974 but absent in 1984 included typical swamp forest species such as *Convolvulus sepium, Echinocystis lobata,* and *Maianthemum canadense*; these were originally present with low coverage and frequencies. Similarly, several species that were "new" to the marsh in 1984, including *Amphicarpa bracteata, Arisaema triphyllum,* and *Thalictrum polygamum,* were also more commonly associated with the swamp forest herb strata. We had previously observed that a number of emergent marsh species of the oxbows occur with high frequency but low cover in the herb strata of the Hatfield forest (Holland and Burk, 1984). In addition, some species were of nearly equal abundance and/or frequency in the forest and the marsh.

HIGH MARSH. High marsh at Hatfield contained more species than any zone of any other marsh sampled through the period. Most high marsh species could be included in one of three broad categories: (1) herbaceous annuals and perennials, many of which also occurred in the adjacent swamp forest, (2) vines, which are characteristic of the herb stratum of swamp forest both at Hatfield and in floodplain forests elsewhere on the Connecticut River (Nichols, 1916), and (3) woody seedlings of swamp forest trees and shrubs. During the 1974–1984 interval, herbaceous species fluctuated in abundance. Vines declined in high marsh, while the coverage and frequency of most species represented by woody seedlings increased. Actual (unrounded) cover values of *Acer rubrum,* for example, rose from 0.02% to 0.11% in the interval while cover values of *A. saccharinum* rose from 0.20 to 1.15%. Larson and Golet (1982) noted that succession from shallow marsh (equivalent to our high marsh) to forested wetlands involves a simple "replacement of one dominant life form by another" and not a major change in the hydrological regime. The increase in woody seedlings in the Hatfield high marsh may suggest the initial stages of this replacement here.

Onoclea sensibilis dominated high marsh on all eight baselines in 1974 and all but one in 1984. Two vines, *Apios americana* and *Vitis riparia,* together contributed slightly more than 10% cover to the high marsh in 1974 and sightly less in 1984.

MID MARSH. *Lemna minor* covered over half the water surface in the Hatfield mid marsh during the relatively dry summer of 1974, often forming a separate stratum beneath emergent vegetation. *Decodon verticillatus* was the most prominent emergent, followed in order of decreasing abundance by *Leersia oryzoides* and *Peltandra virginica.*

In the freshwater tidal lower reaches of the Connecticut River, Metzler and Damman (1985) found *Peltandra virginica* the most abundant species in herbaceous marsh communities within frequently flooded, low-lying swales, sometimes growing in association with *Leersia oryzoides.* At Hatfield by 1984, *Peltandra virginica* had become the dominant emergent. *Decodon verticillatus* remained important, but *Leersia oryzoides* was surpassed in abundance by *Lemna minor, Decodon verticillatus,* and *Onoclea sen-*

sibilis on the single baseline it had dominated ten years earlier. *Lemna minor* was much less abundant, possibly because of strong currents associated with the late May flood; total vegetative cover decreased correspondingly.

Low marsh. In 1974, *Lemna minor* and *Nuphar variegatum* together covered more than one-third of the open water surface in low marsh at the Hatfield oxbow. Little vegetation occurred along three baselines. Submerged aquatics, including *Cabomba caroliniana* in association with *Ceratophyllum demersum* and *Elodea nuttallii,* provided slightly less than 10% cover below the water surface.

In 1984, *Lemna minor* and *Nuphar variegatum* were still dominant, and one sparsely vegetated baseline had been colonized by *Nymphaea odorata* and *Nuphar variegatum.* The abundances of *Cabomba caroliniana* and *Ceratophyllum demersum* were little changed, but *Elodea nuttallii* was absent. The first Massachusetts collections of *Cabomba caroliniana* were made in South Pond, the lower segment of the Hatfield oxbow, in 1930 (Manning, 1937). *Cabomba caroliniana* had been observed at that site since the early 1920's and has become generally widespread elsewhere in New England in the interval (Burk et al., 1976; Hellquist and Crow, 1984).

Ned's Ditch

The nine ponds containing marsh vegetation at Ned's Ditch are effectively separated during much of the year by more continuous stands of swamp forest and buttonbush (*Cephalanthus occidentalis*) swamp. During intervals of flooding, high water extends throughout the forest, swamp, and marshes. Nonetheless, Ned's Ditch is the only one of the three study sites that does not receive regular flow from a source other than the Connecticut River, and during periods of drought, some or all of the ponds may dry out. During September of 1980, for example, we observed that all of the ponds except for the two sections of the old Mill River bed completely lacked standing water; later that season what had been formerly low marsh and open water supported dense fruiting stands of *Bidens* spp.

The swamp forest at Ned's Ditch is older, more extensive, and better developed than the swamp forest at Hatfield, and is dominated by *Acer saccharinum* in association with *Quercus palustris* and *Fraxinus pensylvanica.* The overall resemblance between the Ned's Ditch marshes and the herbaceous stratum of the Ned's Ditch swamp forest is nearly as high as the resemblance between the Ned's Ditch marsh floras at the two sampling intervals (Table 2). Most species of the Ned's Ditch marshes also occur in the adjacent forests, where they vary in abundance from year to year in apparent response to fluctuating water levels (Holland and Burk, 1984). The dynamic interaction of marsh and swamp forest vegetation is exemplified by the distribution within the oxbow of *Ludwigia polycarpa,* currently on the threatened list in Massachusetts (Sorrie, 1987). *Ludwigia polycarpa* was present in the high marsh in 1974 and became established in adjacent swamp forest quadrats by 1975; it had disappeared from high marsh by 1984 but persisted in the forest, becoming re-established in the marsh in 1985 (M. M. Holland, pers. obs.).

Table 3 lists the dominant taxa of high, mid, and low marsh in each of the nine Ned's Ditch ponds in 1974 and in 1984. Most changes in dominance probably resulted from variations in water level throughout the study period and do not reflect long-term trends of marsh development.

HIGH MARSH. In 1974, *Cornus stolonifera, Vitis riparia,* and *Onoclea sensibilis* were the most important high marsh species in order of decreasing abundance (Table 1). Only *Osmunda regalis* also occurred at cover greater than 5%. Four ponds lacked a zone of high marsh, probably as a result of heavy shading by adjacent stands of buttonbush swamp. *Cornus stolonifera* dominated high marsh at two ponds, *Osmunda regalis* at one, *Onoclea sensibilis* at one, and *Onoclea sensibilis* overlain with vines of *Vitis riparia* at one (Table 3).

By 1984, *Onoclea sensibilis* and *Osmunda regalis* had increased to become the most prominent high marsh species, while *Cornus stolonifera* and *Vitis riparia* declined (Table 1). Throughout Ned's Ditch, *Cephalanthus occidentalis* had been damaged by the late May flood. A high marsh dominated by *Osmunda regalis* had developed in one pond where high marsh had previously been lacking, and a similar new high marsh dominated by *Onoclea sensibilis* had developed in another; two ponds still lacked high marsh (Table 3). *Cornus stolonifera* retained dominance at one pond but at the other was surpassed by *Onoclea sensibilis, Osmunda regalis,* and other species. *Osmunda regalis, Onoclea sensibilis,* and *Onoclea sensibilis/Vitis riparia* remained dominant in

Table 3. Dominant taxa of high, mid, and low marsh in each of the 9 Ned's Ditch ponds in 1974 and 1984. For ease of comparison, only generic names are listed; see text for species occurring and pond locations. The notation "sparse veg." indicates the zone supported only scanty plant cover or open water; "no zone" indicates the zone was absent.

Pond #	Year	High Marsh	Mid Marsh	Low marsh
1	1974	*Osmunda*	*Osmunda*	*Nuphar*
	1984	*Osmunda*	*Sium/Sparganium*	*Nuphar*
2	1974	no zone	*Cephalanthus*	*Nuphar*
	1984	*Osmunda*	*Cephalanthus*	*Nuphar*
3	1974	*Onoclea*	*Cephalanthus*	*Nuphar*
	1984	*Onoclea*	*Cephalanthus*	*Nuphar*
4	1974	no zone	*Cephalanthus*	sparse veg.
	1984	*Onoclea*	*Cephalanthus*	*Ranunculus*
5	1974	*Cornus*	no zone	*Potamogeton*
	1984	*Onoclea*	*Leersia*	sparse veg.
6	1974	no zone	*Cephalanthus*	sparse veg.
	1984	no zone	*Bidens*	sparse veg.
7	1974	no zone	*Cephalanthus*	*Nuphar*
	1984	no zone	*Bidens*	*Nuphar*
8	1974	*Onoclea/Vitis*	*Cephalanthus*	*Nuphar*
	1984	*Onoclea/Vitis*	*Nuphar*	*Nuphar*
9	1974	*Cornus*	no zone	*Nuphar*
	1984	*Cornus*	*Nuphar*	*Potamogeton*

ponds where dominant in 1974. *Bidens* spp., *Thelypteris palustris, Dulichium arundinaceum,* and seedlings of *Acer saccharinum* had all increased by 1984 to occupy high marsh in at least five ponds.

MID MARSH. In 1974, *Cephalanthus occidentalis* occupied 68% of the sampled area (Table 1) and dominated mid marsh at six ponds (Table 3). *Osmunda regalis* was dominant at one pond, while two ponds lacked mid marsh.

In 1984, *Cephalanthus occidentalis,* despite a sharp decline in cover (Table 1) retained dominance in three ponds, but was replaced as dominant by *Bidens* spp. in two ponds and by *Nuphar variegatum* in the other. In one pond, *Sium suave* and *Sparganium americanum* in nearly equal abundance had replaced *Osmunda regalis* as dominant. *Nuphar variegatum* had established a new zone of mid marsh in one pond as had *Leersia oryzoides* in another (Table 3).

LOW MARSH. *Nuphar variegatum* was dominant in low marsh in six ponds in Ned's Ditch in 1974 and *Potamogeton pectinatus* in one; two ponds contained open water with only sparsely scattered low marsh vegetation (Table 3). *Nuphar variegatum* continued to dominate five ponds in 1984 but was replaced as dominant in one by *Potamogeton pectinatus.* The zone of low marsh previously dominated by *P. pectinatus* contained only open water when sampled in 1984. *Ranunculus flabellaris* had increased overall and dominated one pond which had little low marsh vegetation earlier; the other pond contained only scattered *Lemna minor, Spirodela polyrhiza,* and *Wolffia columbiana.*

Throughout the study period, *Lemna minor* and *Spirodela polyrhiza* occurred regularly, though sparsely, in low marsh in most or all of the ponds. A third member of the Lemnaceae, *Wolffia columbiana,* was first collected in Massachusetts in the vicinity of Ned's Ditch in 1933 (Manning, 1934). However, this species was not observed anywhere in Ned's Ditch or in the adjacent sections of the Northampton oxbow during the period 1973–1975 (Burk, 1977; Sackett, 1977 op. cit.). *Wolffia columbiana* has recently become abundant at a number of western Massachusetts sites (Burk et al., 1976; Hellquist and Crow, 1982) and apparently invaded Ned's Ditch within the decade.

The Whately Oxbow

Vegetational and floristic changes in the Whately marshes over the decade were marked by a sharp decline in species richness in high and mid marsh (Table 1). These changes could be attributed in part to human activities, including waste disposal, in the vicinity of the single pond. Marsh species at Whately are generally excluded from the adjacent swamp forests, which are dominated by *Acer rubrum* above an herb stratum comprised of ferns and spring-blooming herbs more typical of upland sites (Holland and Burk, 1984). As a result, resemblance between the Whately marshes and the herbaceous stratum of the Whately swamp forest is extremely low (Table 2). The 1974 flora of the Hatfield marsh did, however, show an unexpectedly high resemblance to the flora of the Hatfield swamp forest; this resemblance was lower in 1984 because of the loss of numerous species from the Whately marsh. Both the Hatfield and Ned's Ditch marshes were more similar throughout the study period to their adjacent swamp forests than to the swamp forests of the other oxbows (Table 2).

High marsh. In 1974, the high marsh at Hatfield was relatively diverse with a mixture of both annual and perennial species present at cover values greater than 5%. The vegetation along the two transects differs substantially. On the northern transect, which crosses the only remaining ponded open water, the most abundant species in order of decreasing cover values (ranging from 15% to 7%) were *Juncus effusus, Agrostis alba, Typha latifolia, Onoclea sensibilis,* and *Leersia oryzoides.* All these were either absent or scantily represented in 1984 except *Onoclea sensibilis,* which had increased to occupy 41% of the zone.

In high marsh on the lower transect in 1974, *Polygonum sagittatum, Onoclea sensibilis, Carex intumescens,* and *Impatiens capensis* were most important with cover values ranging from 23% down to 11%. By 1984, cover of *Onoclea sensibilis* had increased to 71%, *Impatiens capensis* to 17%, and *Symplocarpus foetidus,* new to the zone, to 8%. Both *Carex intumescens* and *Polygonum sagittatum* had declined to cover values less than 0.5%.

Of the 39 high marsh taxa recorded at Whately in 1974, 25 species also occurred in the herb strata of swamp forest at either Hatfield or Ned's Ditch or both of these regularly flooded sites. Seventeen (68% of the total shared) had disappeared from the Whately marsh by 1984; since these were not replaced by other taxa, overall diversity decreased sharply.

MID MARSH. Mid marsh on the northern transect was dominated in 1974 by *Typha latifolia* with *Lemna minor* second in abundance. In 1984, *Typha latifolia* was absent, replaced in part by *Sparganium androcladum. Lemna minor* was less abundant; species richness had dropped from ten to four.

Leersia oryzoides, with 34% cover, dominated mid marsh on the lower transect in 1974, followed in abundance by *Impatiens capensis* and *Sparganium androcladum.* In 1984, *Symplocarpus foetidus* was dominant, followed in abundance by *Impatiens capensis* and *Onoclea sensibilis. Leersia oryzoides* and *Sparganium androcladum* were no longer present in the zone.

LOW MARSH. *Nuphar variegatum* dominated low marsh on the northern transect in 1974 and by 1984 had increaed in combination with newly established *Nymphaea odorata* to occupy over 52% of the surface. *Lemna minor* and *Spirodela polyrhiza* occurred sparsely in this zone in 1974; by 1984, *Spirodela polyrhiza* had disappeared, but at Ned's Ditch, *Wolffia columbiana,* previously absent, had invaded.

Low marsh on the lower transect was dominated by *Sparga-*

nium androcladum in association with *Impatiens capensis, Lemna minor,* and *Spirodela polyrhiza* in 1974. By 1984, *Sparganium androcladum* had declined to 4% cover; *Lemna minor, Impatiens capensis,* and *Spirodela polyrhiza* were absent; and *Myosotis scorpioides, Symplocarpus foetidus,* and *Vallisneria americana* were present at cover values of 3% or lower.

Conservation

ROLE OF EXOTIC SPECIES. The invasions and subsequent spread of non-native species have classically been considered both causes and effects of habitat disruption. In the marshes of the southeastern portion of the prehistoric Northampton oxbow and throughout two ponds within Arcadia Wildlife Sanctuary, several non-native species including *Iris pseudacorus* L., *Lythrum salicaria,* and *Marsilea quadrifolia* L. are common and considered "management concerns" by the wildlife sanctuary staff (McGuire, 1989). However non-native species as a group (excluding the two spreading indigenous species, *Cabomba caroliniana* and *Wolffia columbiana*) are not abundant in the oxbow marshes included in this study. *Lysimachia nummularia,* a minor component of the Ned's Ditch marsh throughout the study period, is an important component of the herb stratum of the Hatfield swamp forest (Table 1). A few non-natives including *Glechoma hederacea, Solanum dulcamara,* and *Taraxacum officinale* were collected in 1974 but not in 1984 and may be regarded as transitory colonists of marsh habitats. *Lythrum salicaria,* a species which has been identified as a "serious threat to native emergent vegetation in shallow-water marshes throughout the northeastern and north-central region" (Thompson et al., 1987) was sampled in the Hatfield high and mid marshes in 1974 but not in 1984. However, *Lythrum salicaria* is now abundant in a disturbed section of the Hatfield oxbow adjacent to a feedlot and road embankment (C. J. Burk, pers. obs. through 1989).

PRESERVATION. We have previously stressed the importance of protection for oxbow habitats (Burk and Holland, 1979; Holland and Burk, 1984). Marsh zones within riparian systems have traditionally been recognized both as discrete communities and as ecotones, the transitions between adjacent plant communities (Holland et al., 1990). Ecotones often contribute extensively to biotic diversity within a region since they frequently support, in addition to species characteristic of the verging communities, species uniquely adapted to the ecotone environment (see di Castri et al., 1988, for a recent review of this topic.) The Massachusetts oxbow marshes represent a unique phase in the transition between the open water of the former river bed and floodplain forest. Their extent is inversely proportional to the age of the oxbow itself, and they contain in many instances relics of formerly more widespread floras and vegetation types. At present, only the prehistoric Northampton oxbow is fully protected as a natural area. Both the Hatfield and Whately oxbows are for the most part privately owned and potentially subject to extensive further disturbance by human activities. Their preservation in a natural state, free of disrupting human influences, demands high management priority.

ACKNOWLEDGMENTS

We have previously thanked those who contributed in various ways to our studies in the period 1973–1977 (Holland and Burk, 1982, 1984). Our debt and gratitude to them has only increased since. In addition we thank Marilyn Bekesch, Alison Coppola, Anne Reilly, and Laurie Sanders for their assistance in the field during 1984–1985. Ms. Reilly and Ms. Sanders also contributed to our analysis of data. The 1984–1985 studies were supported in part by the Faculty Fund of the College of New Rochelle, NY, and by the Committee on Faculty Compensation and Development at Smith College.

LITERATURE CITED

Barbour, M. G., J. H. Burk and W. D. Pitts. 1987. Terrestrial Plant Ecology, 2nd ed. Benjamin/Cummings Pub. Co., Menlo Park, CA.

Burk, C. J. 1973. Partial recovery of vegetation in a pollution damaged marsh. Water Resources Research Center. Univ. Mass. Amherst Publ. no. 27.

———. 1977. A four year analysis of vegetation following an oil spill in a freshwater marsh. J. Appl. Ecol. 14: 515–522.

———, S. D. Lauermann and A. L. Mesrobian. 1976. The spread of several introduced or recently invading aquatics in western Massachusetts. Rhodora 78: 767–772.

——— and M. M. Holland. 1979. Stone Walls and Sugar Maples: An Ecology for Northeasterners. Appalachian Mountain Club, Boston, MA.

——— and ———. 1981. A decade of change in a freshwater marsh in western Massachusetts. Bull. Ecol. Soc. Amer., Program Issue 62: 94.

CLEMENTS, F. E. AND V. E. SHELFORD. 1939. Bio-ecology. John Wiley and Sons, New York.

COLLINS, R. F. AND M. SCHALK. 1937. Torrential flood erosion in the Connecticut Valley, March, 1936. Amer. Jour. Sci. 34: 293–307.

DAUBENMIRE, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row, New York.

DI CASTRI, D., A. J. HANSEN AND M. M. HOLLAND. 1988. A New Look at Ecotones: Emerging International Projects on Landscape Boundaries. Biology International Special Issue 17., Paris, France.

FERNALD, M. L. 1950. Gray's Manual of Botany, 8th ed. American Book Co., New York.

HAMPSON, G. R. AND E. T. MOUL. 1977. Salt marsh grasses and number two fuel oil. Oceanus 20: 25–30.

——— AND ———. 1978. No. 2 fuel oil spill in Bourne, Massachusetts: immediate assessment of the effects on marine invertebrates and a 3-year study of growth and recovery of a salt marsh. J. Fish. Res. Board Canada 35: 731–744.

HELLQUIST, C. B. AND G. E. CROW. 1982. Aquatic Vascular Plants of New England: Part 5. Araceae, Lemnaceae, Xyridaceae, Eriocaulaceae, and Pontederiaceae. New Hampshire Agric. Exp. Sta. Bull. 523, University of New Hampshire, Durham.

——— AND ———. 1984. Aquatic Vascular Plants of New England: Part 7. Cabombaceae, Nymphaeaceae, Nelumbonaceae, and Ceratophyllaceae. New Hampshire Agric. Exp. Sta. Bull. 527, University of New Hampshire, Durham.

HOLLAND, M. M. AND C. J. BURK. 1982. Relative ages of western Massachusetts oxbow lakes. Northeastern Geology 4: 23–32.

——— AND ———. 1984. The herb strata of three Connecticut River oxbow swamp forests. Rhodora 86: 397–415.

——— AND B. A. SORRIE. 1989. Floristic dynamics of a small island in Lake Winnipesaukee, New Hampshire. Rhodora 91: 315–338.

———, D. F. WHIGHAM AND B. GOPAL. 1990. The characteristics of wetland ecotones, pp. 171–198. *In:* R. J. Naiman and H. Decamps, Eds., Ecology and Management of Aquatic Terrestrial Ecotones. Parthenon Press, London.

JACKSON, S. T., R. P. FUTYMA AND D. A. WILCOX. 1988. A paleoecological test of a classical hydrosere in the Lake Michigan dunes. Ecology 69: 928–936.

JAHNS, R. H. 1947. Geological features of the Connecticut Valley, Mass., as related to recent floods. Geol. Survey Water-Supply Paper 996. U.S. Government Printing Office, Washington, D.C.

LARSON, J. S. AND F. C. GOLET. 1982. Models of freshwater wetland change in southeastern New England, pp. 181–185. *In:* B. Gopal, R. E. Turner, R. G. Wetzel and D. F. Whigham, Eds., Wetlands: Ecology and Management. International Scientific Publishers, Jaipur, India.

LAUERMANN, S. D. AND C. J. BURK. 1976. The flora of Penikese Island: the centennial collection and its biogeographic implications. Rhodora 78: 707–726.

MANNING, W. C. 1934. *Wolffia* in Massachusetts. Rhodora 36: 420.

———. 1937. New records for the Connecticut Valley in Massachusetts. Rhodora 39: 186–188.

Metzler, K. J. and W. H. Damman. 1985. Vegetation patterns in the Connecticut River flood plain in relation to frequency and duration of flooding. Naturaliste Canada. 112: 535–547.

McGuire, B. A. 1989. Ecological Management Plan for Arcadia Wildlife Sanctuary. Massachusetts Audubon Society, Lincoln, MA.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York.

Nichols, G. E. 1916. The vegetation of Connecticut—V. Plant societies along rivers and streams. Bull. Torrey Bot. Club 43: 235–264.

Robinton, E. D. and C. J. Burk. 1971. The Mill River and its floodplain in Northampton and Williamsburg, Mass.: a study of the vascular plant flora, vegetation, and the presence of the bacterial family Pseudomonadaceae in relation to patterns of land use. Water Resources Res. Center, Univ. Mass., Amherst. Completion Report 72–4.

Shelford, V. E. 1963. The Ecology of North America. U. Illinois Press, Urbana.

Simpson, G. G. 1965. The Geography of Evolution. Chilton Co., Philadelphia, PA.

Sorrie, B. A. 1987. Notes on the rare flora of Massachusetts. Rhodora 89: 113–196.

Thompson, D. Q., R. L. Stuckey and E. B. Thompson. 1987. Spread, impact, and control of purple loosestrife (*Lythrum salicaria*) in North American wetlands. U.S. Fish Wildl. Serv., Washington, D.C.

M. H. H.
ECOLOGICAL SOCIETY OF AMERICA
9650 ROCKVILLE PIKE
BETHESDA, MD 20814

C. J. B.
DEPARTMENT OF BIOLOGICAL SCIENCES
SMITH COLLEGE
NORTHAMPTON, MA 01063